The University of California, Davis Advanced Canopy Atmosphere Simulation Algorithm (ACASA)

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ACASA consists of an advanced computer model, to simulate water use, photosynthesis, energy fluxes, and turbulent characteristics associated with plant canopies. It has been shown to accurately describe the microclimate through profiles of wind speed, wind direction, air temperature and humidity, and radiation, in addition to the exchange of material such as water and carbon dioxide. It can be used for estimating elements of the ecosystem carbon balance and water exchange with the atmosphere, such as evapotranspiration. The model, though complex, can be run on laptops and desktop PC platforms. Recent work has shown that this model can not only be used as a 'stand-alone' model for fields, but can be nested into regional scale weather models for improved forecasting and simulations.

The model scales from the leaf and soil level to the canopy (field) level. Leaves are included as 9 sunlit leaf angle classes and one shaded class, for each vertical layer (a total of 10-100 layers) in the canopy. The model has been developed for over the past 20 years, starting with the thesis work of Tilden Meyers under the direction of Kyaw Tha Paw U (Paw U et al., 1985; Meyers and Paw U, 1986, 1987). Full physiological response is described using the Farquhar-von Caemmerer-Ball Berry photosynthesis/stomatal response models (Farquhar and von Caemmerer, 1982; Collatz et al. 1991). These linked models, needed for stomatal control of evapotranspiration, automatically yield carbon dioxide exchange. Respiration is modeled as a function of tissue temperature, and for the soil, soil temperature. Urban modifications include anthropogenic CO_2 source parameterization dependent on population and urbanization type. Radiation transfer through leaves and canopy elements is approximated with two-stream physics, and split into the visible, near infrared and thermal infrared spectral regimes (Norman, 1979); urban building modifications have been added recently. The full energy budget and associated temperature of surface elements (leaves, canopy parts, urban canyons, etc.) is solved using an accurate quartic solution (Paw U and Gao, 1988). Turbulent exchange between the layers and the atmosphere is described by a higher-order closure model developed originally by Meyers and Paw U (1987) and then developed further (Pyles et al. 2000; Pyles et al., 2004). This turbulent transfer scheme allows 'counter-gradient' transport that many other simpler models are unable to describe (Meyers and Paw U, 1986, 1987). Precipitation interception and snowpack ablation are included (Fig. 1)

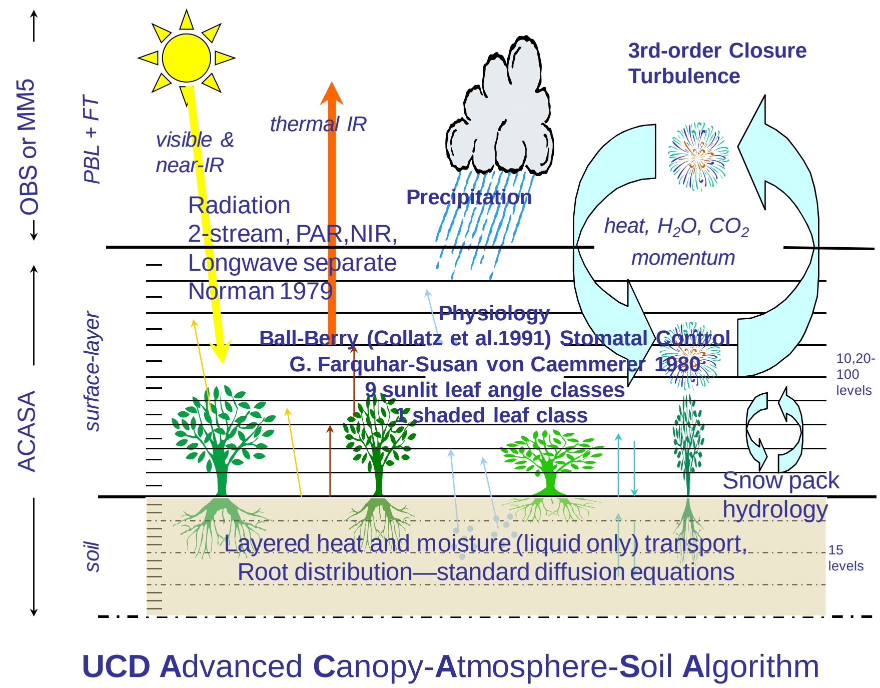
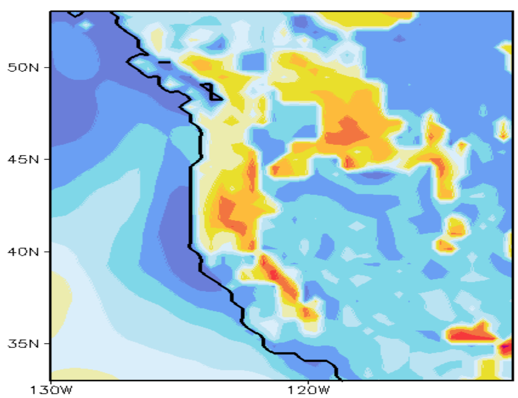


Fig. 1. Schematic of the ACASA model.

This type of soil-plant-atmosphere model has been shown to accurately simulate key wind direction and speed profiles, turbulence, flux and mean scalar profiles within and above canopies (Meyers and Paw U, 1987; Pyles et al., 2000; Pyles et al., 2004). ACASA has shown its ability for regional scale simulations in its successful linkage to the fifth-generation Penn State/NCAR Mesoscale model (Pyles et al. 2003). Preliminary carbon and water exchange for a specific case study of the western U.S. were shown to be realistic (Pyles et al. 2003; figure 2).

Required input to ACASA falls into two main categories, weather and land surface. Ambient meteorological data at the top of the model domain is needed, such as air temperature, humidity, incoming shortwave and longwave radiation, carbon dioxide concentration, precipitation, and wind speed and direction. Land surface characteristic variables include such variables as element reflectivity (such as leaves, branches, building walls, sidewalks, etc.), element area, plant physiological response parameters, and soil parameters.

Recent collaborations with researchers from around the world have led to modifications in ACASA to make it compatible with various land use types, including urban and suburban landscapes (Australia: Melbourne project; Italy: BRIDGE project), snow pack (SNOW-Mips), vineyards (Italy: University of Sassari), and forests (German forest: Bayreuth University; Univ. California Davis: Wind River Old Growth Forest). Preliminary results for the snow pack study shows snowpack disappearance is generally predicted within one day. In addition, ACASA is being linked to WRF and data sources needed for regional simulations (from the coastal areas to the Sierras) are being identified.



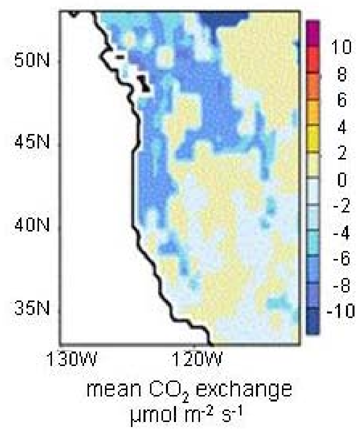


Figure 2a&b: Actual ET estimates (2a) and CO_2 exchange (2b) maps from the linked ACASA-MM5 model (Pyles et al., 2003).

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